

PROCEEDINGS

AMERICAN SOCIETY OF CIVIL ENGINEERS

AUGUST, 1955



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HIGHWAY DIVISION

{Discussion open until December 1, 1955}

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Printed in the United States of America*

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE \$0.50 PER COPY

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This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

MANPOWER FACTORS IN AN AUGMENTED¹ HIGHWAY PROGRAM

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SYNOPSIS

The prospect of a considerably augmented program of highway construction raises serious problems of engineering manpower. In view of some practical limit to the size of the total pool of available engineering manpower, factors in addition to recruitment require consideration. Possibilities of the segregation of professional and non-professional functions, and the utilization of specially-trained vocational personnel for the performance of the latter are discussed. A study of the patterns of use of private engineering firms in the performance of highway functions is reviewed. Suggestions are made concerning the possibilities of and need for the development of further streamlined procedures and devices for reducing manpower requirements.

An expanding post-war economy and unprecedented increase in use of highway motor vehicles have resulted in severe demands upon the highway plant. Notwithstanding appreciable increases in highway investment since 1946, the rate of construction and rehabilitation of highway facilities has been inadequate to meet the demands imposed by motor-vehicle usage, according to numerous state and nationwide estimates.⁵ Proposals to come before the Congress of the United States, and plans for highway development in many of the states, now point toward an augmented rate of highway construction.

The growing tempo of highway activity has raised a number of difficult problems in highway administration, not the least of which is that of obtaining personnel, especially engineering personnel, both in sufficient number and with adequate experience or training. To meet the manpower requirements

1. A paper prepared for presentation at the San Diego Convention of the American Society of Civil Engineers, Highway Division Session, February 11, 1955.
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5. See, for example, The President's Advisory Committee on a National Highway Program, A Ten-Year National Highway Program, Washington, D. C., U. S. Govt. Print. Office, 1955; also Engineering News-Record, December 30, 1954.

implicit in carrying forward programs of highway construction now under consideration will require special efforts, and may require a reorganization of methods of performing highway engineering functions.

The Manpower Problem

While the efforts, in recent years, of state highway departments, city and county road agencies, and private engineering organizations to recruit engineering personnel are general testimony of the growing need for technical manpower, a recent nationwide survey by the Highway Research Board⁶ affords some dimensions to the problem. A canvass was made late in 1954 of the state highway departments to obtain an estimate of present shortages and the requirements for an expanded program.

The results of the Highway Research Board survey show that in 1954, the number of personnel employed directly by the state highway departments in professional engineering classifications totalled nearly 18,000. In addition, private engineering firms furnished services estimated to be the equivalent of 4000 engineers. The study indicates that, even with the combined effort of the highway departments and the private engineering firms, there was a shortage of nearly 4000 highway engineering personnel in professional grades in 1954.

The 1954 programs of the state highway departments alone involved a capital outlay of about \$2.7 billion. If the programs of the state highway departments were doubled (an acceleration not out of line with the proposal of the President's Advisory Committee on a National Highway Program⁵), the minimum number of personnel needed in the engineering classifications would be 32,000, according to the Highway Research Board report; this would be an increase of approximately 50 per cent over the total equivalent number of personnel in professional engineering classifications, utilized in state highway department programs in 1954.

The estimates cited above do not include the needs of cities, counties or the toll-road agencies. Also, it may be noted in passing, the figures quoted from the Highway Research Board survey are based on existing engineering classifications; no attempt was made to segregate numbers of personnel doing, or required for, professional engineering functions.

Roughly 4 billions of dollars annually are currently being spent on highway programs including all jurisdictions and we are now talking about spending upwards to 10 billions of dollars annually. An interesting disclosure of the Highway Research Board report is the fact that without improvement in utilization of our highway engineers a little over 4000 additional engineers will be required for each one billion dollars of additional highway work. This is roughly the number of civil engineering graduates throughout the nation in 1953.⁷

Since the total pool, current and potential, of experienced professional engineering manpower is limited, it does not appear that a satisfactory solution to the manpower problem will be obtained if there should take place merely shifts of personnel from one state or agency to another, or from public to private employ or vice versa. Rather, the over-all solution will probably have to be attained by a combination of several devices, such as:

6. Campbell, M. Earl and Schureman, L. R., *Technical Personnel Study*, presented at the Annual Meeting of the Highway Research Board, Washington, D. C., January 1955.

7. *The Journal of Engineering Education*, February 1954.

- 1) More effective utilization of available and potential engineering talent, by relieving professional employees of duties which can be performed adequately by clerical and specialized vocational personnel, and by non-engineering administrative personnel.
- 2) Use of the resources of private engineering firms for assignments where effective use of such organizations can be made and where the over-all efficiency of the programs can be augmented.
- 3) Increased use of mechanized procedures, such as computational devices and photogrammetric mapping.
- 4) Further streamlining of office and field methods, such as increased use of standard and simplified designs wherever possible.
- 5) Recruitment of increased numbers of young graduates through wider dissemination of information concerning opportunities for challenging careers, backed up by attractive personnel policies and salaries.

Effective Utilization of Personnel

Data assembled by the National Manpower Council⁸ indicates that the ratio of technicians to professionals in engineering is considerably lower than other professions such as medicine and health. One reason cited for this situation has been the lack of clear distinctions between purely technical and professional work; the distinctions are apparently much clearer in some of the other professions. Young professional engineering graduates, especially in highway engineering, are often classified in professional grades, but are commonly assigned to vocational⁹ tasks, not only as a necessary part of their on-the-job training, but as a traditional practice.

The normal pattern of entrance into, and advancement in, the engineering profession is for engineering graduates to go through a fairly long period of apprenticeship before assuming positions of professional responsibility. Many engineering graduates today, however, have had advance training in their field of professional specialization, and the trend toward advanced training is increasing. It would seem that in large organizations, especially, some mechanism for placing these graduates into positions requiring professional skills as rapidly as possible would make fuller use of their specialized training and serve as a greater incentive for young engineers to pursue highway engineering as a career.

A program for improving the utilization of professional highway engineers will require careful analysis of job requirements and a close inspection of job practices. It may be appropriate to realign some of the traditional job-titles to conform more closely to the functions they actually represent. An analysis of this sort will necessarily have to concern itself with distinctions between professional and vocational duties. The number of vocational-type personnel required effectively to support specific professional tasks requires

8. National Manpower Council. Proceedings of a Conference on the Utilization of Scientific and Professional Manpower. Held October 7-11, 1953, at Arden House, Harriman Campus of Columbia University. New York, N. Y., Columbia University Press, 1954. 197 p.

9. In this paper the term "vocational" is used to describe those functions which require certain aptitudes and skills of a specialized nature, as distinguished from those functions commonly described as "professional" which require education or long experience to develop breadth of knowledge and exercise of judgment. Some of the vocational functions are drafting, computing, certain levels of materials inspection and field surveying.

consideration. Indications are that there are considerable differences among state highway departments classifying personnel as professional and sub-professional. It may be appropriate to review the scope of vocational work in highway engineering on a national scale both in public and private employ. In the medical profession, for example, vocational personnel carry out not only comparatively elementary tasks but also tasks of great complexity requiring formal training and license.

In highway engineering we may be requiring professional engineers to perform a relatively high proportion of tasks that are actually of a quasi-professional nature, and could be readily handled by vocational-type personnel who could be trained in a relatively short time, either on-the-job, or through specialized training courses of a few weeks or months duration. It is quite possible that if some of these tasks were performed by vocational-type personnel under appropriately organized supervision, the over-all productive capacity could be increased with only small increase in professional personnel.

Another aspect of conservation of professional engineering manpower arises in the higher echelons of engineering organizations. While administrative functions necessarily require the attention of engineers in advanced professional ranks, where policies exist under which the purely administrative engineering positions are higher salaried, there is provided an incentive for professional engineers to leave the technical field. The problem arises largely in agencies employing large numbers of engineers. Although it is recognized that the administrative functions in highway engineering are extremely important and require top-notch talent and ability, it is equally important to recognize that organizations sometimes suffer from the lack of experienced professional personnel to perform these technical functions because of lack of incentive, salary-wise, to remain in this field. A review of the policies concerning differentials in salaries of the higher-grade technical engineers and administrative engineers may be appropriate.

The foregoing remarks have alluded to only a few suggestions related to improving the utilization of professional highway engineers. The subject is complex and cannot be defined within any precision. Much thought is given to this problem by highway agencies, but much more will undoubtedly, be required. Since the manpower shortage confronting highway agencies probably will not be solved solely by recruitment, it would seem that the problem of using professional highway engineers more effectively deserves serious and continuous attention by the profession. Important gains in utilization of our professional highway engineers can take place only if current practices can come under constant critical review.

Utilization of Resources of Private Engineering Firms

The use of private engineering firms to supplement the staffs, of highway agencies who for one reason or another cannot, or do not desire to, carry out their program entirely with their own personnel may be one of the devices for mitigating personnel shortages, particularly for small highway jurisdictions which do not have large or fairly well-established staffs.

Highway Engineering includes many functions, ranging from broad planning and policy making to detailed design and supervision of construction. If private engineering firms are to be utilized to a greater extent in the future it would seem desirable to determine where, in this broad area of activity, private firms can be effective in assisting highway agencies.

The bulk of the highway engineering function to date has been performed predominantly by agencies of government; therefore no general body of policy or no uniform practices, relatively speaking, appear to have developed with respect to the utilization of engineering services provided by private engineering firms, as a supplement to regular and continuing highway agency functions.

To obtain and analyze information concerning the policies and practices of highway agencies now using private engineering firms for the performance of highway engineering functions, a study was undertaken during the latter part of 1954 by the Institute of Transportation and Traffic Engineering of the University of California.¹⁰ The study was confined principally to the practices of state agencies; information was obtained by questionnaires mailed to all state highway departments, by interviews with the principal officials of a number of state highway departments, and with two toll-road authorities. For comparison, information was also obtained from two Federal agencies and from three large private industrial organizations in California.

From the response of 44 state highway type agencies concerning current practices, it was found that approximately 80 per cent of the departments use the services of private engineering firms for performing highway engineering functions for one or more purposes. A sampling of those departments which utilize the services of private engineering firms indicated that consulting firms were utilized on work pertaining to less than 1 per cent, and to as high as 25 per cent of the current volume of construction.

Highway Departments and other agencies have employed private engineering firms in the following categories of work: (1) for the performance of specialized work or phases of work, where a department lacked some particular type of specialized personnel, or where a department did not consider that it could justify employing specialized personnel on a permanent basis for some particular type of work, (2) for the performance of functions which would otherwise normally be handled by the Department's own staff principally due to (a) the inability of the Department to obtain additional personnel for some reason, usually low salaries, or (b) infeasibility of adding temporary staff during relatively short peak periods, and (3) the preparation of reports where independent outside appraisal is desired. The most frequent reason given for the engagement of private engineering firms was to handle peak loads. The second most frequent reason given was that the engineering service desired was special with respect to most of the engineering ordinarily performed by an existing staff.

The most predominant use of consultants by state highway departments at present is for final design and the preparation of plans and specifications for construction. Preliminary planning is occasionally given to consultants, but the supervision of construction and the acquisition of rights of way is seldom handled by consultants. Instrument surveys are performed primarily by the departments' own forces; on the other hand, a number of states contract for the preparation of topographic maps through the medium of aerial photography, and also for certain types of routine checking and inspection of materials purchases.

In the construction of toll-roads, either under the jurisdiction of a highway department, or under a separate state authority, private engineering firms have performed nearly all the phases of engineering.

10. Davis, H. E., Berry, D. S., and Snowden, W. S., "A Study of the Use of Private Engineering Firms for the Performance of Various Highway Engineering Functions" presented at the Annual Meeting of the Highway Research Board, Washington, D. C., January 1955.

Contractual Arrangements

The selection of a consulting firm is based primarily on the competence of the firm to do a specific piece of work and its ability to perform the work within the time required by the employing agency. Some agencies develop a "panel" of consultants considered to be competent, and final selection is made after detailed conferences with available consultants included in the panel. Agreements with respect to fees are usually arrived at by negotiation.

Contracts for highway engineering services are closely analogous to those for construction. Like construction contracts, they are generally designated by the method used in arriving at the amount of the compensation. The types of engineering contracts in common usage for highway work generally follow the pattern outlined in ASCE Manual of Engineering Practice No. 29.

For design and the preparation of plans and specifications about one-half of the public agencies contacted require that the contracts be drawn up on a lump-sum basis while the other half permit the fee to be based on a percentage of the estimated or actual construction costs. For preliminary project reports the lump-sum type of contract is prevalent. For items such as foundation and materials investigation, where costs in advance cannot be accurately determined, the cost plus fee type of contract seems to be favored. In a majority of the cases the fee is expressed as a percentage of the salary costs.

Based on data from 15 states, consultants fees for final design and the preparation of plans and specifications for bridges and roadways range from two to five per cent of the cost of construction; the magnitude of the fee depends upon the size of the project, its complexity, and the amount of basic data furnished to the consultant by the contracting agency. In the majority of cases studied, these fees do not include advance planning work, foundation and exploration surveys, or extensive instrument surveys. Since the bulk of the information furnished by state highway departments concerned fees for final design and the preparation of plans and specifications no definite pattern of fees could be discerned from isolated information on supervision of construction.

To compare the cost of doing work by a highway department with its own forces, and the cost of doing the same work through the employment of private engineering firms is a difficult matter. Generally, highway departments, as public agencies, are required to do their accounting under rules established through law and/or by the legal fiscal agent or department of the state government. Such fiscal accounting for legal purposes often does not provide the same breakdowns of accounts as the kind of cost accounting which would be done for technical cost control or comparisons. Lacking a basis for precise comparison of costs, opinions were solicited from 28 states. On the basis of opinions, approximately 80 per cent of the states solicited replied that it was more costly to have the work performed by private engineering firms, 10 per cent stated that the use of private firms resulted in lesser costs and 10 per cent stated that the costs were about the same.

Shifts of Personnel from Public to Private Employ

Private engineering firms, generally, have been able to offer salaries higher than public agencies; consequently, many engineers in the employ of public agencies have been attracted toward private employment. A number of the contract forms for highway engineering services contain a "no-raiding" clause which prevents consulting firms from employing engineers from the department for which they are performing the service. On the other hand,

such clauses do not prevent firms from employing engineers of other states and other jurisdictions.

A canvass of over 40 state highway departments indicates that while the problem appears to be serious in only a few states now, it may become serious in other states in the future with an accelerated program.

Practices of Non-Highway Agencies

Selected districts of two Federal agencies were interviewed during the course of this study; these differed to some extent in their use of consulting firms. A District of the Corps of Engineers uses private firms only for the preparation of plans and specifications for construction. All preliminary planning, materials and foundation surveys and supervision of construction is performed by the District's own forces. On the other hand, a District of the Bureau of Yards and Docks utilizes consulting firms not only for the preparation of plans and specifications for construction but also for advance planning, although the use of consultants for the former purpose is by far the more predominant. Both agencies use their own forces to acquire rights of way. Consulting firms are selected primarily on the basis of their competence and capacity for performing the services desired. Contractual pay arrangements are based primarily on a lump-sum basis.

Two of the surveyed industries report that consulting firms have been assigned about 25% of the work of the industries' central engineering offices over the past several years. Most of this work has been assigned to avoid temporary staff expansions. Much of it has involved cases where both engineering and construction have been undertaken by a single firm, and in these cases it has been common to contract for all engineering beyond broad preliminary planning. These two industries have also used consultants extensively for specialized types of engineering in order to avoid segmentation of the organization's staff into small specialized groups. The third surveyed industry reported continual use of consultants, but for only about 3 per cent of its engineering, and only for specialized work or preliminary design. It may be pertinent that this industry has expanded much less rapidly than the other two.

Streamlined Procedures

Another factor which may be worthy of further consideration and study by highway management, is the additional development and application of methods and devices which reduce manpower requirements, both professional and vocational. Appreciable studies in this direction have been made in recent years by some highway departments; for example, the use of photogrammetric methods in preliminary surveys has conserved time and manpower in the field; the handling of great volumes of traffic survey data by tabulating and sorting machines could never have been done with the manpower available.

Machines have been designed and successfully used to perform many types of complex computations in the aircraft and other industries. It is believed that important possibilities exist for developing machine methods and short-cut procedures for performing more of the tasks traditionally performed by engineering personnel.

It is recognized that the development and installation of machine methods usually represents a costly outlay and a difficult change over; when personnel are readily available, there exists little incentive to incur the costs and difficulties. However when large volumes of work are in prospect for a

considerable period, and the manpower problem becomes acute, the ultimate savings may make the exploitation of such methods worth while.

The increased use of standard plans and simplified designs and specifications has been developed by a number of highway departments. Further exploitation of this practice can conserve professional manpower.

An additional possibility for some conservation of manpower in the field, may lie in procedures for measurement of pay quantities. While difficult problems of legal responsibility and of maintaining control are involved, the possibilities of balancing greater tolerances on measurements of pay quantities and corresponding reduction in field engineering costs, against somewhat greater materials or construction costs, may be worthy of study.

Recruitment of Engineering Personnel

Under the demands for engineering output occasioned by the increases in highway development which have already taken place, the immediate and most obvious solution to the manpower problem has been sought in terms of additional and new personnel. Many aspects of the recruitment problem have been analyzed and reported upon time and again in highway organizations. However, many highway agencies have not been able appreciably to improve their competitive positions in the professional engineering personnel market.

As has been pointed out in many places, two basic factors in attracting personnel under competitive conditions are: (1) salaries, (2) employment conditions, such as merit systems, retirement systems, job security, opportunities for advancement. For the young engineer, attractions which often loom importantly also are the challenge of the work, and the possibilities of developing real professional responsibility as rapidly as possible.

A further and longer-range step in the process of recruitment is, then, the communication to high school graduates, and to engineering undergraduates, the opportunities for highly satisfactory and challenging careers in the field of highway engineering. Certainly highway engineering should be able to get its reasonable share of engineering graduates if offers can be backed up by good personnel policies.

CONCLUDING REMARKS

An increasing tempo of highway development, and prospects of still further increase in the years immediately ahead, has highlighted the problem of manpower to perform the highway engineering functions. It is unlikely that the demands can be fully met by recruitment of additional experienced professional highway engineers or by new engineering graduates, whose numbers will remain inadequate for the next few years.

It seems likely that attention must be given to all possibilities for increasing the output of highway facilities by devising ways of utilizing the available pool of manpower with increasing effectiveness, by developing procedures for reducing manpower requirements in the performance of some kinds of work, as well as attracting what new personnel may become available.

Under a further augmented highway program, private engineering firms may aid increasingly in the performance of a number of engineering functions, but the total manpower pool, which includes engineers in both public and private employ, has some practical limits. Hence the real and pertinent question will be where the services of private firms can be utilized most effectively.

The more effective utilization of engineering manpower, whether in public or private employ, raises problems as yet unresolved. It is believed that attention can usefully be given to (1) ways and means of separating quasi- and non-engineering work from professional engineering work, and the development of specialized personnel to perform such non-professional duties, and (2) methods and devices for reducing manpower requirements, by increased mechanization of some phases of functions such as computing, and by further introduction of streamlined or shortcut procedures.

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